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Self-compacting concrete obtained by the use of kaolin wastes

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HIGHLIGHTS

▶ The successful use of kaolin wastes in the production of self-compacting concrete.
▶ Reduction of the cost of concrete production.
▶ Mitigation of environmental impact.

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ABSTRACT

A self-compacting concrete (SCC) is characterized by its special capacity of filling ability, passing ability and resistance to segregation by the action of its own weight without the presence of other external forces. These fresh properties are obtained thanks to the use of filler, where the limestone one is mostly used. Numerous industries produce a great amount of solid wastes, some suitable for use as filler in the production of SCC. This study aimed to develop a SCC with inclusion of wastes from the manufacturing of kaolin, through an optimum dosage of kaolin wastes and superplasticizer (sp) which were well established from the experiments. The paste dosage was defined by Marsh funnel and mini-slump tests and fresh properties of concrete were measured by L box, U box, J ring, V funnel and Abrams cone. The use of kaolin wastes in SCC production is pioneering. The mix-design method used was successful and it was validated by the several fresh properties results which provided to the concrete a SCC characteristic flowing behavior. Finally, including industrial waste in SCC has brought significant environmental benefits.

1. Introduction

Each day the level of technological demand for concrete grows. According to Mehta and Monteiro [1], developments in concrete technology are the result of an attempt to overcome certain deficiencies of conventional concrete mixtures of Portland cement. The self-compacting concrete began to be developed at the University of Tokyo, Japan, just over 20 years ago [2], mainly due to the need to overcome the problems as the vibration of the concrete in complex structures or the difficulty of filling the formworks with large amount of reinforcement, where the concrete needs to present a good passing ability property to go through [3]. Indeed, a self-compacting concrete (SCC) is defined as the concrete that can flow under its own weight and completely fill the formwork even in the presence of a high density of reinforcement bars, without any vibration, while still maintaining homogeneity [4,5]. Due to these advantages, according to Assié et al. [6], soon conventional concrete (CC) can be replaced by the SCC in many applications. However, according to Domone [7], a SCC has a large range of mix possibilities. So, for all applications and requirements, there still remains a considerable gap in order to improve the mix design for greater efficiency and greater economy.

Among the new studies to produce concrete, in general, inclusion of industrial waste in its composition has been considered, in order to reduce costs and minimize environmental impact. Through the preservation of non-renewable resources and reducing the aggression to the environment, such use represents an alternative way to minimize the consumption of cement and granite aggregate [8].

This work aimed to develop a self-compacting concrete with addition of waste from the manufacture of kaolin, more specifically the coarse kaolin waste (KW2) and the fine kaolin waste (KW1). The procedure used for determining the SCC was then as follows:

_ Find the compatibility of the superplasticizer admixture with the materials of concrete.
_ Determine the optimal dosage of kaolin wastes in the mix.

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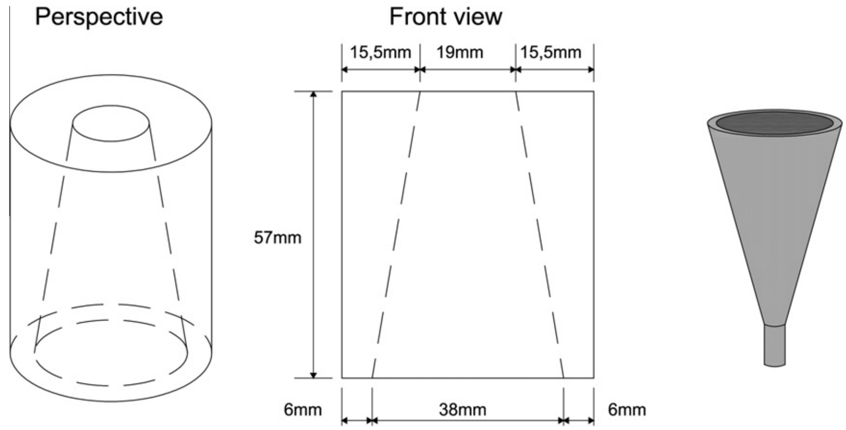

Fig. 1. Mini-slump and Marsh funnel tests for the optimization of the paste.

_ Test filling capacity, passing ability and resistance to segregation, in order to classify a concrete as a SCC.

2. Literature review

Cement, fine and coarse aggregates, admixtures and filler constitute a SCC. Due to these admixtures and filler, SCC fresh properties shall vary easily. The more constituents needed to produce a SCC, the more difficulty encountered to determine the adequate proportion among them.

According to Sedran and de Larrard [9], SCC production is very sensitive to variations in its constituents, and then the criterion for choosing them should be carefully made.

The aspects that define concrete as a SCC are its filling capacity (fluidity), passing ability, and resistance to segregation properties.

Based on the method proposed by Torralles-Carbonari et. al. [10], one of the SCC dosage methods was developed by Gomes [11]. This methodology divides the procedure into two separate steps: obtain the paste constituents and achieve an aggregate skeleton with less granular voids. The method determines the optimum amount of paste to fill the gaps that still exist in the aggregate skeleton, thus providing the characteristics of a SCC.

The fresh properties can be measured by a rheometer or by other experimental devices. Gomes proposed to measure them using the Abrams cone, J ring, U box, L box and V funnel. Properties and devices are associated one to another as shown below:

Filling capacity: Abrams cone and V funnel.
Passing ability to pass through reinforced bars: J ring, U box and L box.
Resistance to segregation: V funnel.

From the Abrams cone test, it is suggested to get two measures: the flowing itself, which means the diameter value of the flow, and also the time it takes for the concrete, when flowing, to reach a circumference whose diameter is 50 cm.

The V funnel is proposed to be used twice, one just after mixing the concrete and another time 5 min later.

For the dosage of the paste, first step of the method, Gomes [11] proposes the use of two different tests: Marsh funnel and Mini-slump (see Fig. 1). The first one has the goal to determine the compatibility between the superplasticizer (sp) and the cement. This test is done twice, 5 min and 60 min after mixing the paste. According to Aïtcin [12], the saturation dosage of the superplasticizer is determined by the intersection of the curves obtained at 5 min and 60 min, in a graph where the *X*-axis is the dosage of SP (%) and the *Y*-axis is the flowing time (s). However, according to Gomes et al. [13], the saturation point is determined when the increase in the dosage of SP does not provoke any further considerable improvement on the paste fluidity.

Kantro [14] developed the mini-slump test in order to obtain the optimum content of fines in the paste.

From this test, the flowing diameter and the time it takes for the paste to reach a circumference with a diameter of 115 mm are measured. According to Gomes [11], the values considered satisfactory are: Flowing = 180 mm ± 10 mm; and Time T115 mm = 3 s ± 1 s.

Concerning the aggregate skeleton, used also by Tutikian [15], it verifies the best compactness among the aggregates to be used, by the bulk density measurement, where the greatest density value will offer the lowest voids content. But the difference between Tutikian's [15] and Gomes' [11] methods is that the one by Tutikian determines the aggregate skeleton including the filler, while the one by Gomes determines the amount of filler by the mini-slump test. Gomes's method assumes that the behavior of the fluidity of concrete is largely governed by the fluidity of the paste, so that it can be developed separately from the aggregate skeleton [16].

Table 1 shows the values accepted as indicators of good workability for SCC, and it was constructed based on the references studied for this research, such as those found in EFNARC [5] and Gomes [11].

3. Materials

3.1. Cement

Due to its availability and its extensive use in construction, Portland cement CP II F 32 (Brazilian specification: 92% clinker + 8% limestone filler – 32 MPa) was chosen.

3.2. Industrial waste

The industrial waste included in this research comes from the manufacture of kaolin. The plant, located in Juazeirinho, in Paraiba State, Brazil, produces the kaolin for the manufacture of papers and ceramics. A finer kaolin waste (KW1) and a coarse kaolin waste (KW2) are rejected during the production of the pure kaolin and thrown away in the natural environment. These wastes KW1 and KW2 were then used in this research.

In Fig. 2, the X-ray diffraction pattern of the kaolin wastes is shown. Both KW1 and KW2 have the same mineralogical composition, differing only in terms of particle size distribution.

To determine the specific area, authors used the method of Blaine, according to the procedure of the NBR NM[2] 76 [17]. The value found for the finer waste was 1959.0 cm^2/g. The grading curve of the finer waste, determined by laser granulometry, is shown in Fig. 3.

[2] NBR NM – Brazilian Standard.